Incidence, depth, and severity of surgical site infections after neurosurgical interventions

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Abstract: Background Today, there are only few reports on the incidence of surgical site infections (SSIs) in neurosurgery. The objective of this work was to determine the rate of SSI at a tertiary neurosurgical department for benchmarking purpose. Methods Data of consecutive patients undergoing neurosurgical treatment between January 2013 and December 2016 were prospectively entered into a registry. SSIs were diagnosed according to the 2017 Centers for Disease Control and Prevention criteria, with severity graded according to the Clavien-Dindo grade (CDG). We analyzed type and length of surgery (LOS), time to SSI, responsible microorganisms, and its association with the functional status (Karnofsky Performance Status = KPS). Results Of n = 5463 procedures, a SSI occurred in n = 106 (1.94%). The highest rates of SSI occurred after vascular (3.4%) and cerebrospinal fluid (CSF) diversion procedures (3%), as well as after procedures performed to treat a previous complication (2.9%). There was no difference in LOS across procedures with and without SSI. The median time between the index procedure and SSI was 15.5 days. SSIs were most frequently diagnosed after hospital discharge (55%). The most common microorganisms were coagulase-negative staphylococci, Staphylococcus aureus, and Escherichia coli. In 62.3% of cases, SSI required invasive treatment (surgical revision). Patients with SSI in the in- and out-patient setting (SSI occurring after hospital discharge) presented both with a median KPS of 80. Conclusions The current report provides an overview on SSI in a contemporary, unselected, large series of patients undergoing modern neurosurgical care for benchmarking purposes. The overall rate of SSI was about 2%, but subpopulations with higher risks were identified where additional measures could be taken to prevent SSI and monitor patients at risk more closely for SSI. Keywords Incidence Complication Morbidity Neurosurgery Surgical site infection Treatment

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Incidence, depth and severity of surgical site infections after neurosurgical interventions

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Abstract

Background: Today, there are only few reports on the incidence of surgical site infections (SSI) in neurosurgery. The objective of this work was to determine the rate of SSI at a tertiary neurosurgical department for benchmarking purpose.

Methods: Data of consecutive patients undergoing neurosurgical treatment between 01/2013 – 12/2016 were prospectively entered into a registry. SSI were diagnosed according to the 2017 Centers for Disease Control and Prevention criteria, with severity graded according to the Clavien-Dindo grade (CDG). We analyzed type and length of surgery (LOS), time to SSI, responsible microorganisms and its association with the functional status (Karnofsky Performance Status = KPS).

Results: Of n=5463 procedures, a SSI occurred in n=106 (1.94%). The highest rates of SSI occurred after vascular (3.4%) and cerebrospinal fluid (CSF)-diversion procedures (3%), as well as after procedures performed to treat a previous complication (2.9%). There was no difference in LOS across procedures with and without SSI. The median time between the index procedure and SSI was 15.5 days. SSIs were most frequently diagnosed after hospital discharge (55%). The most common microorganisms were coagulase negative staphylococci, Staphylococcus aureus and Escherichia coli. In 62.3% of cases, SSI required invasive treatment (surgical revision). Patients with SSI in the in- and out-patient setting (SSI occurring after hospital discharge) presented both with a median KPS of 80.

Conclusions: The current report provides an overview on SSI in a contemporary, unselected, large series of patients undergoing modern neurosurgical care for benchmarking purposes. The overall rate of SSI was about 2%, but subpopulations with higher risks were identified where additional measures could be taken to prevent SSI and monitor patients at risk more closely for SSI.

Key words: incidence; complication; morbidity; neurosurgery; surgical site infection; treatment

Abbreviations and acronyms

ASC = Active Surveillance Culture

AST = Active Surveillance Testing

CDC = Centers for Disease Control and Prevention

CDG = Clavien-Dindo grade

CI = confidence interval

CoNS = coagulase-negative Staphylococci

CSF = cerebrospinal fluid

EVD = external ventricular drainages

HIA = healthcare associated infections

IQR = interquartile range

KPS = Karnofsky Performance Status

LOS = length of surgery

MRI = magnetic resonance imaging

NHSN = National Healthcare Safety Network

OR = odds ratios

Sp = species

SSI = surgical site infections

Introduction

Understanding the incidence and pathophysiology of surgical site infections (SSIs) is the key to their prevention. SSI can range from superficially infected dehiscence to life-threatening conditions. Their impact on the patient's subjective well-being is always negative and significant,[17] and their management requires considerable expenses for the health care systems.[14] A previous study found that patients who developed a SSI were twice as likely to die, 1.6 times as likely to require intensive care treatment, and more than five times as likely to be readmitted to the hospital.[14] As shown in a survey of healthcare associated infections (HAIs) by the European Centre for Disease Prevention and Control, SSIs were the second most common reason, accounting for 19.6% of all HAI between 2011 and 2012.[32] A multicenter report showed the overall prevalence of SSI to be around five per cent (5.4%) for general surgery.[31] Large-scale national SSI surveillance programs have been shown to reduce the rates of SSI, [5, 13] but they do not include neurosurgical procedures.[2]

In neurosurgery in general, prospective large-scale studies reporting robust SSI estimates are currently lacking and a wide range of SSI rates between 1-8% for cranial procedures and 0.5-18.8% for spinal procedures have been reported.[4, 6, 21] We have previously reported SSI in a small cohort of patients operated on with intraoperative magnetic resonance imaging (MRI).[10] In the present study, we determined the rates of SSI in a large cohort at a tertiary neurosurgical department for benchmarking purposes.

Methods and Materials:

Patient Identification

This was a retrospective analysis of a prospective, database containing complication and outcome data of all consecutive patients that underwent neurosurgical operative treatment at the Department of Neurosurgery, University Hospital of Zurich, Switzerland.[24] From the registry, data of all patients operated at our institution between 01/2013 – 12/2016 were extracted and their medical history and diagnosis of SSI were re-evaluated.

Definition of Surgical Site Infections (SSI)

SSI had to meet the latest Centers for Disease Control and Prevention (CDC) criteria.[5] Accordingly, an SSI was registered if it occurred in the time interval of either 30 or 90 days, depending on the depth of the SSI and the procedure performed (e.g., 30 days for carotid endarterectomy and laminectomy, and 90 days for craniotomy, spinal fusion and ventricular shunts).[5]

Incisional infections were sub-classified into superficial (involving only skin or subcutaneous tissue), deep (involving fascia and/or muscle; Supplementary Table 1) or organ/space infections (Supplementary Table 2).

Due to the particular cranial anatomy with a thin muscle layer, we slightly modified these definitions for cranial procedures. Superficial SSI involved skin, subcutaneous tissue, fascia and/or muscle. Infections affecting the bone were classified as deep SSI. Every SSI involving the epidural space or deeper layers was classified as organ/space infection (Supplementary Table 3). If multiple tissue levels were affected, the deepest infection type was reported.[5]

SSI prevention, wound care and postoperative management

Single-shot antibiotic prophylaxis (1.5g Cefuroxime) was administered 30 minutes before skin incision and repeated every four hours during the operation. The skin preparation was consistent, typically including localized shaving, skin cleaning with "Benzinum medicinale", followed by disinfection with alcoholic agent (Chlorhexidin 2% ®, B. Braun Medical AG, Sempach, Switzerland). There was no intraoperative use of antibiotic solution for irrigation. Wound closure was not standardized, but usually included re-adaptation of each layer by tight sutures with staples on the pericranium (except for in pediatric patients) and (resolvable) sutures on the skin for incisions on the remaining parts of the body. Administration of antibiotics was not continued after surgery, unless the procedure was performed to wash out a (suspected) infection.

Surgical wounds were inspected daily, starting from the 2nd postoperative day and until discharge. The primary care physician was asked to check on the wound within 1-2 weeks postoperative. The neurosurgical follow-up involved consultations after six and 12 weeks, continued on an individual basis afterwards. Patients were instructed to present themselves earlier if any deviation of the normal healing process occurred.

Assessment of complications, functional status and further variables

To classify a SSI as a postoperative complication, the Clavien-Dindo grading scale (CDG) was used (Table 1). This system is based on the type of therapy required to treat a complication, thus reflecting the amount of resources required to manage.[7]

The patient's functional status was assessed by the Karnofsky Performance Status (KPS).[27] It was assessed at discharge for patients experiencing a SSI during the hospitalization (in-patient setting) and at time of hospital re-admission for patients diagnosed with SSI after hospital discharge (out-patient setting).

Statistical considerations

The primary outcome was the rate of SSI at 30 or 90 days postoperatively, depending on the type of procedure. Descriptive statistics and chi-squared or Fisher's exact tests were used, as appropriate, to compare SSI rates between categories. Logistic regression allowed for the estimation of the effect size of certain predictors of SSI, with results expressed as odds ratios (OR) and 95% confidence intervals (CI). With Bonferroni post-hoc adjustment to account for multiple testing, p-values < 0.005 were considered statistically significant.

Ethical considerations

Scientific workup of the registry data was approved by the institutional review board and patient consent was waived. The authors report no conflicts of interest.

Results

In the surveillance period, a total of n=5462 surgeries were performed in n=3901 patients. In this cohort, we recorded n=106 SSI in n=100 patients (Figure 1), translating into an overall SSI rate of 1.94%. Five patients developed more than one SSI (four had two SSIs, one had three SSIs).

Of the 106 SSIs, 28 (26.4%) were superficial, 13 (12.3%) were deep and 65 (61.3%) were organ/space infections. Figure 2 illustrates the percentage of SSI, relative to the total number of surgeries.

SSI rates in relation to age, sex and indication for surgery

Table 2 shows the indications for surgery. The highest absolute SSI rate was observed after vascular procedures, followed by oncological and CSF-related procedures. Low absolute SSI rates were seen in particular after spinal and functional procedures.

The highest relative SSI rate was observed after vascular procedures (3.43%), followed by CSF-related procedures and those required to treat a previous complication (Figure 3). Patients undergoing a vascular procedure were twice as likely as the average patient to experience a SSI (OR 2.12, 95% CI 1.39 – 3.24, $p<0.001$).

Time to infection

The median time between the index procedure and SSI diagnosis was 15.5 days (interquartile range (IQR): 9, 26). For superficial SSIs, the median time was 15.5 days (IQR: 9, 23), for deep infections 31 days (IQR: 19, 58) and for organ/space infections 12 days (IQR: 8, 24). The frequency distribution of the data shows a left skew (Figure 4). Eighty-six SSI (81%) occurred during the first 30 postoperative days.

Forty-eight SSI (45%) were diagnosed prior to hospital discharge, and 58 cases (55%) occurred after discharge. All of those cases led to patient re-admission.

Length of surgery (LOS)

Data on LOS was available for n=4177 procedures, including n=101 procedures followed by a SSI. LOS was not significantly higher for procedures with (mean 167±13 min (SD); range 15-555 min) compared to procedures without SSI (mean 151±2 min (SD); range 5-900 min; $p=0.187$).

Microorganisms

Of the 106 cases of SSI, 69 (65%) had a positive culture (missing or negative in the remainder). The microorganism most frequently cultured in SSI was coagulase-negative Staphylococci (CoNS) followed by Staphylococcus aureus and Escherichia coli. A polymicrobial infection was seen in 31 (29%) of the cases (Table 3).

Treatment and severity-grading of SSI complications

Surgical revision under local (CDG 3a) or general anesthesia (CDG 3b) was performed in 65/106 (61.3%) patients (Figure 5). Deep and organ/space infections were always treated surgically, with the only exception being CSF-infections (meningitis/ventriculitis) without previous shunt placement or any other foreign body in situ. Superficial infections were treated surgically in 16/28 cases (57%). All patients were treated with antibiotics following intraoperative sampling. Superficial infections were less frequently managed conservatively by intensive wound care without (CDG 1) or with antibiotics alone (CDG 2; 12/28; 43%).

There were no cases requiring intensive care management (CDG 4a/b) and there was no mortality attributable to SSI (CDG 5; Figure 5).

Functional status

The functional status of patients with SSI occurring in the in- (median KPS 80; mean 67.5, SD 25.6) and out-patient setting (median KPS 80; mean 73.7, SD 20.4) was similar. Patients with superficial SSI had a mean KPS of 71.3 (median 70), patients with deep SSI a mean KPS of 71.3 (median 85) and patients with organ/space SSI a mean KPS of 70.3 (median 80).

Discussion

We set out to determine the rates of SSI in a large, unselected and contemporary patient series treated at a neurosurgical department. Analyzing prospective data from n=5462 procedures, the most striking findings were that the overall rate of SSI was relatively low (1.94%) and that SSI were twice as likely to appear after a neurovascular surgical procedure.

SSI rates

Being the second most common HAI, potentially preventable and both a measure for a hospital's and a surgeon's quality, SSI rates have been in the focus of interest throughout the last years.[31] Our overall SSI rate was relatively low with 1.94%, given that the overall SSI rate across all surgical fields was reported to be 5.4%.[2] Compared to other surgical fields, in neurosurgery wound healing problems and SSI appear less common, possibly due to the rich microvascular network between different vascular systems of the external carotid artery with generally good perfusion and oxygenation in the head and neck region.[18] Reported SSI rates in the neurosurgery literature remain variable and in general apply to subsets of surgical procedures only. For cranial procedures rates between 1-8% and for spinal surgeries rates between 0.5-18.8% have been published.[4, 6, 9, 10, 16, 19, 21] Comparison of our results with previous studies must be done with caution. Our report followed the 2017 definition of the CDC,[5] but older studies have used different SSI definitions.

Surgical Indication and SSI

In contrast to most previous studies, our data provide an overview on SSI rates across a broad variety of common indications. This enabled us to compare the likelihood of SSI between patient cohorts.

We noticed that patients in the "vascular" indication group were twice as likely to develop a SSI (OR 2.12, 95% CI 1.39 – 3.24, $p<0.001$), which remained significant even using a conservative statistical approach with Bonferroni post-hoc adjustment. Patients harboring (ruptured) vascular pathologies are severely ill, require long treatment on the intensive care unit and/or placement of external ventricular drainages (EVD), which is associated with a high intrinsic risk to develop a SSI. EVD-associated meningitis/ventriculitis is a common complication, occurring in 0-22% of cases.[23, 28] In our series, 11/31 vascular patients with SSI required placement of an EVD, of which eight developed an Organ/Space infection and three developed a superficial infection. Subsequently, the high number of EVD placement together with general immuno-depression in this cohort [25] could be among the possible explanations for the high incidence of SSI in the "vascular" group. Another explanation could be the high complexity of vascular surgical procedures, leading to longer LOS with

more bacterial access to the surgical field and reduced local immunological defense by retractor-induced reduction of soft-tissue and meningeal blood perfusion.[12] Even though these mechanisms are plausible, the present data do not support such a conclusion for our cohort, as there was no statistically significant association between SSI rate and LOS.

Time to infection

We found that the majority (81%) of SSI occurred during the first 30 days, whereas most (55%) were detected after discharge. We used the CDC definition for the timing of SSI, including a maximal limit of 30 or 90 days postoperative, depending on the surgical procedure.[5] However, 23 infections occurred after the "official follow-up" of 30 or 90 days, and these excluded infections would have increase our overall SSI rate from 1.94% to 2.36. Considering that this corresponds to a growth of 22% in the overall SSI rate, one should critically question, whether excluding patients after 30 or 90 days is justified. Delayed infections by microorganisms with low virulence, such as Propionibacterium acnes, may only manifest after several months.[22] The issue with a maximal time limit for SSI by the CDC has been discussed by the Dutch nosocomial surveillance network and the possibility of slight underestimation in the SSI rate was considered acceptable.[15]

Microorganisms

The microorganisms most often found were CoNS (34%), followed by Staphylococcus aureus (20%), in line with previous studies.[1, 11, 19] It is believed that those are commonly acquired from a patient's endogenous flora, less frequently from the operating room environment (exogenous). The time of greatest risk for SSI is between incision and wound closure. Pre- and postoperative antisepsis can only reduce the contamination of the patient's skin with endogenous flora, but not eliminate it. As a result, gram-positive cocci from the patient's endogenous flora at or near the site of surgery remain the leading cause of SSI.[1]

Impact of SSI

To classify the severity of SSI complications, we used the CDG system.[3, 20, 24, 26, 29, 30] Most patients with SSI required revision surgery (CDG 3a/b); only CSF-infections without placement of a foreign body and some of the superficial infections were treated conservatively without (CDG 1) or with antibiotics alone (CDG 2). Since patients with SSI were hospitalized for surgery and i.v.-antibiotic application (usually at least for 2 weeks), the data suggest – besides a high impact on the patient – high direct and indirect health-care costs associated with SSI, as well. A review from 84 studies estimated the costs of SSI in Europe to range between 1.47 – 19.1 billion Euros, with SSI increasing the healthcare costs by the factor three.[31]

SSI following cranial neurosurgical procedures frequently present as meningitis, epi- or subdural empyema or cerebral abscess.[8] As a result, SSI may lead to significant morbidity or even mortality.[14] The CDG is not suitable to estimate the effect of a given complication on the patient condition,[3, 20, 24, 26, 30] which is why we additionally analyzed the association between SSI and the performance status (KPS). Our results indicate that in our cohort, SSI had no major impact on the functional status. However, if the diagnose and management of SSI is delayed, major secondary damage with impact on the performance status can occur.

Strengths and Limitations

The underlying data was prospectively collected by a large and varying team of physicians. It is possible that some did not apply consistent and valid definitions for SSI. As all recorded SSI were reviewed and double-checked, we are confident that the rate of false-positive SSI is close to zero. However, while we took great care in registering all SSI, some may have gone unnoticed. This is particularly true for minor infections, which cleared up spontaneously or were treated by the general practitioner without notifying the neurosurgical team. Patients with major infections are always referred back to our hospital. Consequently, we assume that the number given here for minor infections (superficial) is the minimum, whereas those for major infection (deep and organ/space) should be accurate.

As a strength of the study, our analysis is based on a prospective, large, unselected database, providing information on many aspects of SSI, including overall rate, predictive factors, timing of SSI occurrence, spectrum of microorganisms, standardized classification according to the CDG and KPS. It thus provides so-far unique, robust estimates for SSI in the field of neurosurgery. Generalizability to other populations, hospitals and settings is limited, but this work provides a starting point that future reports can compare to.

Implications and next steps

At our hospital, we continue to collect data collection pertaining to the incidence of SSI in our prospective patient registry. The determined SSI rates now serves as benchmark, against which the incidence of SSI is continuously compared at quarterly dedicated meetings. If increase of the SSI rate should be detected, immediate measures can be undertaken to determine the reason for and again decrease the SSI rate. Also, our group currently develops and evaluates methods to detect postoperative complications (including SSI) early, allowing to react before secondary – and possibly permanent – damage to patient health has occurred.

Conclusions

The present report found the SSI rates for general neurosurgery to be around 2%. This information should be useful to other departments and for health-care politics. The surveillance and transparent publication of SSI rates is not only important for benchmarking purpose, but also for implementing effective infection control programs.

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Ethical approval: Scientific workup of the registry data was approved by the institutional review board and patient consent was waived.

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Figure legends:

Figure 1: Patient cohorts with and without surgical site infections (SSI).

Figure 2: Illustration of the percentage of surgical site infections (SSI), relative to the total number of surgeries: superficial SSI (0.5%), deep SSI (0.2%), and organ/space SSI (1.2%).

Figure 3: Relative frequency of surgical site infections (SSI), sorted by indication for surgery. Most SSIs occurred after vascular procedures (3.43%), followed by CSF-related (3.01%) and procedures to treat a previous complication (=Complications; 2.91%).

Figure 4: Frequency distribution of time between surgery and diagnosis of surgical site infections (SSI) in days (illustrated as percentage of total SSI). The frequency distribution shows a skew to the left. In 81% of the cases the SSI occurred within the first 30 postoperative days.

Figure 5: Clavien-Dindo grading scale (CDG) of the 106 surgical site infections (SSI). Sixty-six of 106 cases (62.3%) required surgical treatment (CDG 3a & CDG 3b).

Appendices

Supplementary Table 1: Centers for Disease Control and Prevention (CDC) Surgical Site Infection (SSI) criteria - incisional SSI (superficial and deep).[5] ASC = Active Surveillance Culture; AST = Active Surveillance Testing; NHSN = National Healthcare Safety Network.

Supplementary Table 2: Centers for Disease Control and Prevention (CDC) Surgical Site Infection (SSI) criteria – organ/space SSI.[5] ASC = Active Surveillance Culture; AST = Active Surveillance Testing.

Supplementary Table 3: Specific sites of an organ/space surgical site infection (SSI).[5]

Table 1: Clavien-Dindo grading scale (CDG) of postoperative complications.

Grade	Definition
Grade I	Any deviation from normal postoperative course, which can be treated without pharmaceutical, surgical, endoscopic or radiological interventions. Excluded from these interventions are antiemetics, antipyretics, analgesics, diuretics, electrolytes and physiotherapy. This grade also includes infections opened at the bedside.
Grade II	Requiring treatment with pharmaceutics other than the ones allowed for grade 1.
Grade III	Requiring surgical, endoscopic or radiological treatment.
Grade IIIa	Intervention not under general anesthesia.
Grade IIIb	Intervention under general anesthesia.
Grade IV	Life-threatening complications requiring intensive care unit (ICU) management.
Grade IVa	Single-organ dysfunction.
Grade IVb	Multiorgan dysfunction.
Grade V	Death of the patient.

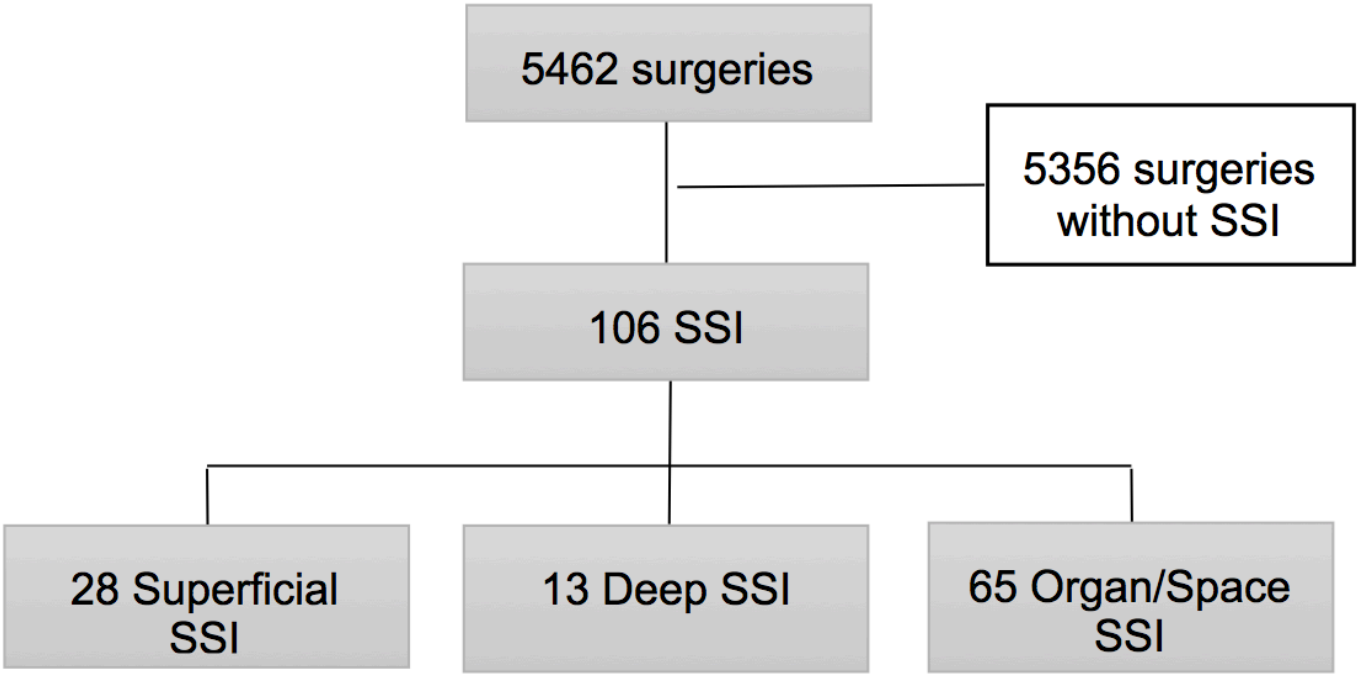
Table 2: Indications for surgery are presented for procedures with or without subsequent surgical site infection (SSI).

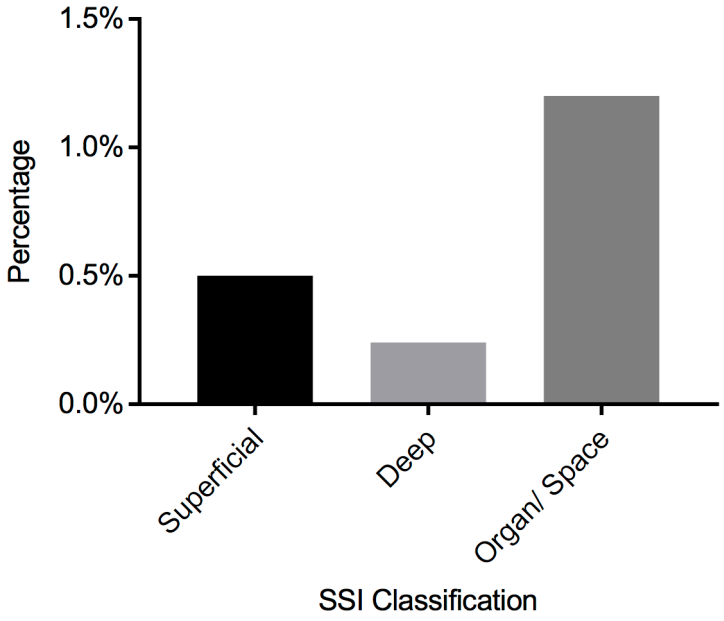
Characteristics	**No SSI**	**SSI**	**p-value**
Indication for surgery			
Tumour, n (%)	1606 (30%)	27 (25%)	0.369
Vascular, n (%)	874 (16%)	31 (29%)	<0.001*
Trauma, n (%)	719 (13%)	12 (11%)	0.627
Spinal, n (%)	610 (11%)	5 (5%)	0.046
Functional, n (%)	569 (11%)	5 (5%)	0.071
CSF-related, n (%)	484 (9%)	15 (14%)	0.101
Previous complication, n (%)	334 (6%)	10 (9%)	0.254
Other, n (%)	160 (3%)	1 (1%)	0.346
Total	**5356 (100%)**	**106 (100%)**	

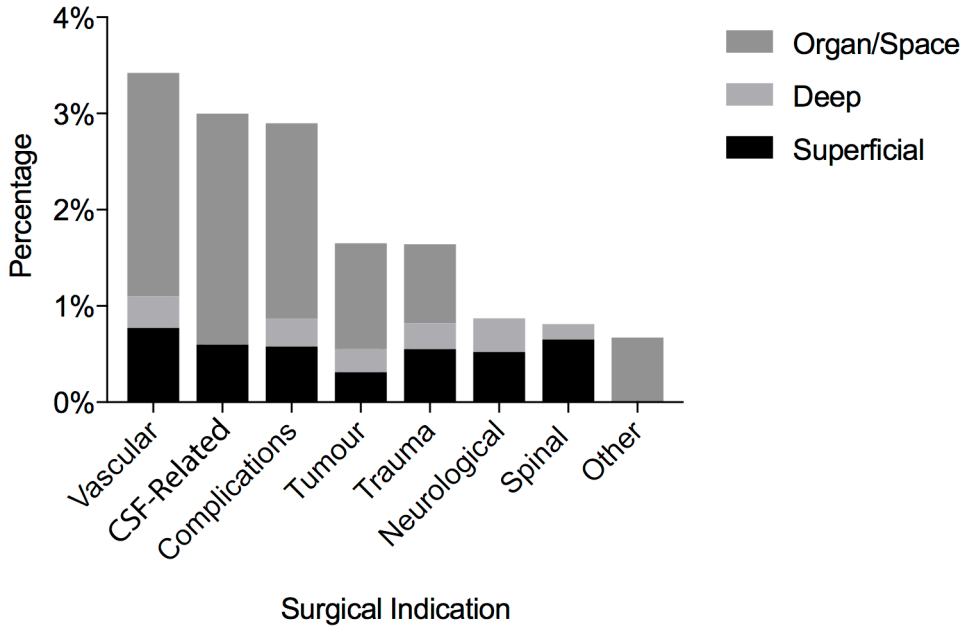
* Significant after Bonferroni post-hoc adjustment.

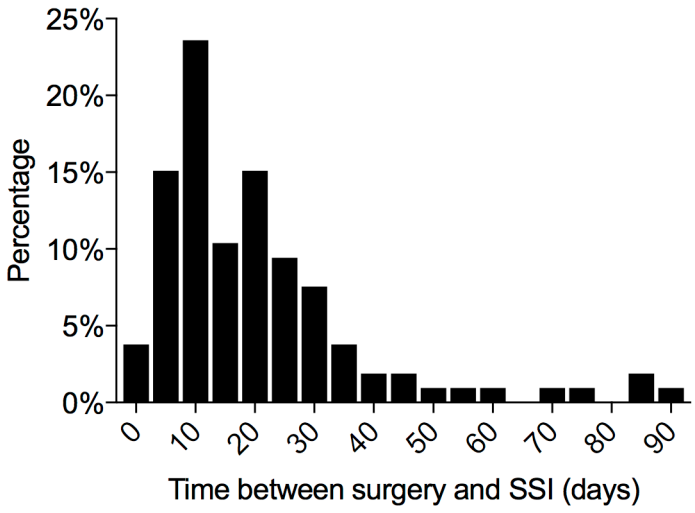
Table 3: Microorganisms cultured from SSI. Coagulase-negative staphylococci (CoNS) were the most frequently cultured microorganisms. Sp. = species.

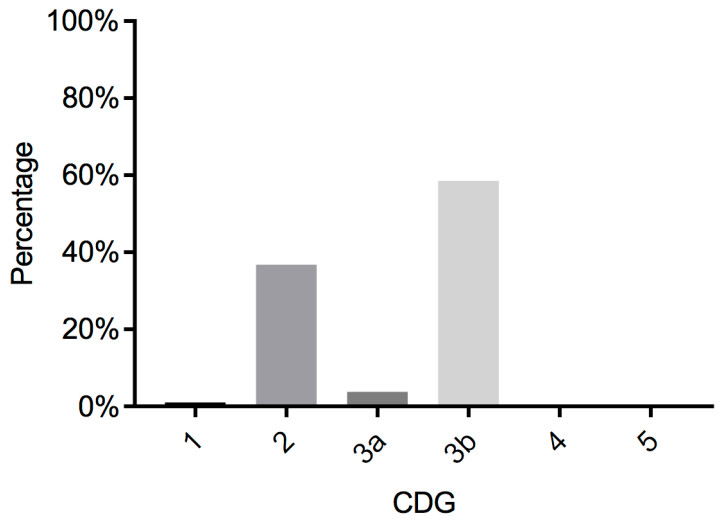
Microorganism	**Number of patients (%)**
CoNS	41 (34%)
Staphylococcus aureus	25 (20%)
Propionibacterium acnes	10 (8%)
Escherichia coli	7 (6%)
Proteus mirabilis	5 (4%)
Streptococcus sp.	5 (4%)
Klebsiella sp.	4 (3%)
Enterobacter sp.	4 (3%)
Citrobacter sp.	3 (2%)
Enterococcus sp.	3 (2%)
Acinetobacter sp.	3 (2%)
Corynebacterium sp.	2 (2%)
Pseudomonas aeruginosa	2 (2%)
Other	8 (6%)


5462 surgeries
5356 surgeries without SSI
106 SSI
28 Superficial SSI
13 Deep SSI
65 Organ/Space SSI


1.5%
1.0%
0.5%
0.0%
Percentage
Superficial
Deep
Organ/ Space
SSI Classification


4%
3%
2%
1%
0%
Percentage
Organ/Space
Deep
Superficial
Vascular
CSF-Related
Complications
Tumour
Trauma
Neurological
Spinal
Other
Surgical Indication


25%
20%
15%
10%
5%
0%
Percentage
0
10
20
30
40
50
60
70
80
90
Time between surgery and SSI (days)


100%
80%
60%
40%
20%
0%
Percentage
1
2
3a
3b
4
5
CDG

Supplementary Table 1: Centers for Disease Control and Prevention (CDC) Surgical Site Infection (SSI) criteria - incisional SSI (superficial and deep).[6] ASC = Active Surveillance Culture; AST = Active Surveillance Testing; NHSN = National Healthcare Safety Network.

Incisional SSI
Superficial SSI
Date of event for infection occurs within 30 days after any operative procedure (where day 1 = the procedure date) ***AND*** involves only skin and subcutaneous tissue of the incision ***AND*** patient has at least ***one*** of the following: a) Purulent drainage from the superficial incision. b) Organisms identified from an aseptically-obtained specimen from the superficial incision or subcutaneous tissue by a culture or non-culture based microbiologic testing method which is performed for purposes of clinical diagnosis or treatment (e.g., not ASC/AST). c) Superficial incision that is deliberately opened by a surgeon, attending physician** or other designee and culture or non-culture based testing is not performed. ***AND*** patient has at least ***one*** of the following signs or symptoms: pain or tenderness; localized swelling; erythema; or heat. d) Diagnosis of a superficial incisional SSI by the surgeon or attending physician** or other designee. ** The term attending physician for the purposes of application of the NHSN SSI criteria may be interpreted to mean the surgeon(s), infectious disease, other physician on the case, emergency physician or physician's designee (nurse practitioner or physician's assistant).
Deep SSI:
The date of event for infection occurs within 30 or 90 days after the operative procedure (where day 1 = the procedure date) according to a pre-specified list.[6] ***AND*** involves deep soft tissues of the incision (e.g., fascial and muscle layers) ***AND*** patient has at least ***one*** of the following: a) purulent drainage from the deep incision.

b) a deep incision that spontaneously dehisces, or is deliberately opened or aspirated by a surgeon, attending physician** or other designee and organism is identified by a culture or non-culture based microbiologic testing method which is performed for purposes of clinical diagnosis or treatment (e.g., not ASC/AST) or culture or non-culture based microbiologic testing method is not performed

AND

patient has at least ***one*** of the following signs or symptoms: fever (>38°C); localized pain or tenderness. A culture or non-culture based test that has a negative finding does not meet this criterion.

c) an abscess or other evidence of infection involving the deep incision that is detected on gross anatomical or histopathological exam, or imaging test

** The term attending physician for the purposes of application of the NHSN SSI criteria may be interpreted to mean the surgeon(s), infectious disease, other physician on the case, emergency physician or physician's designee (nurse practitioner or physician assistant).

Supplementary Table 2: Centers for Disease Control and Prevention (CDC) Surgical Site Infection (SSI) criteria – organ/space SSI.[6] ASC = Active Surveillance Culture; AST = Active Surveillance Testing.

Organ/Space SSI
Date of event for infection occurs within 30 or 90 days after the operative procedure (where day 1 = the procedure date) according to a pre-specified list[6] ***AND*** infection involves any part of the body deeper than the fascial/muscle layers, that is opened or manipulated during the operative procedure ***AND*** patient has at least ***one*** of the following: a) purulent drainage from a drain that is placed into the organ/space (e.g., closed suction drainage system, open drain, T-tube drain, CT guided drainage) b) organisms are identified from an aseptically-obtained fluid or tissue in the organ/space by a culture or non-culture based microbiologic testing method which is performed for purposes of clinical diagnosis or treatment (e.g., not ASC/AST). c) an abscess or other evidence of infection involving the organ/space that is detected on gross anatomical or histopathological exam, or imaging test evidence suggestive of infection. ***AND*** meets at least ***one*** criterion for a specific organ/space infection site listed in Supplemental Digital Content 3. These criteria are found in the surveillance definitions for specific types of infections chapter.

Supplementary Table 3: Specific sites of an organ/space surgical site infection (SSI).[6]

Sites of Organ/Space Infections:
Osteomyelitis
Disc space
Intracranial, brain abscess or dura
Meningitis or ventriculitis
Spinal abscess without meningitis
Arterial or venous infection